3D Printing with CLASS
Making Models for Education and Outreach Using Satellite Weather Imagery

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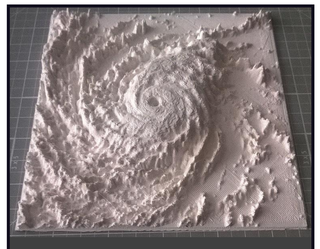
Introduction

Physical models of hurricanes, typhoons, and tropical cyclones shift our perspective on their real-world counterparts, providing a unique and engaging way for us to experience the scale, context and spatial relationships of large storms. Thanks to the increased availability of 3D printers and free and low-cost software for developing digital models, students, educators, outreach professionals, and the general public now have the capability to transform satellite imagery into human-scale cyclone models — to hold a hurricane in their hands.

Presented here are three new hurricane models specifically designed for 3D printing. Each was constructed by merging concurrent GOES visible and infrared images in NOAA's CLASS archive[1] and converting the result to a digital mesh usable by 3D printers. The models and the original images used to make them are now available on NASA's 3D Resources website.[2] This presentation gives an overview of how the models were made.

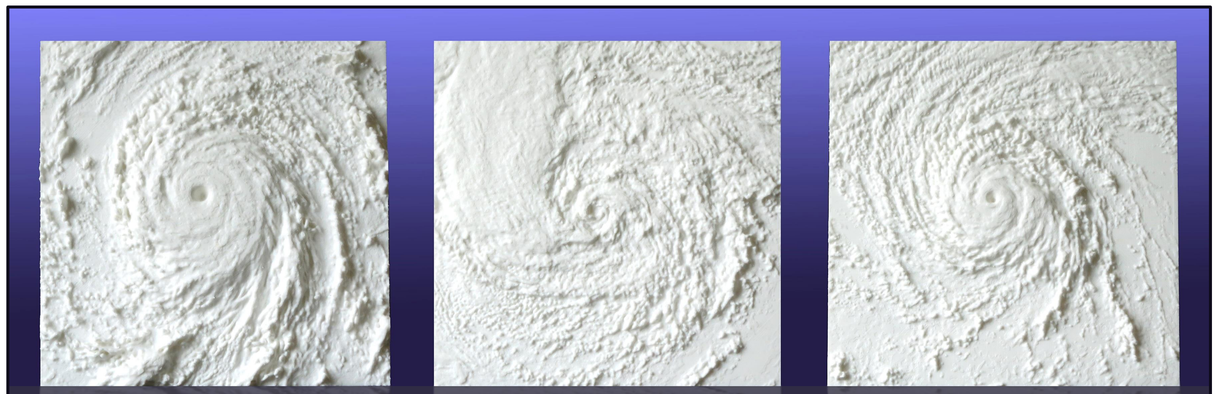
Outreach Potential



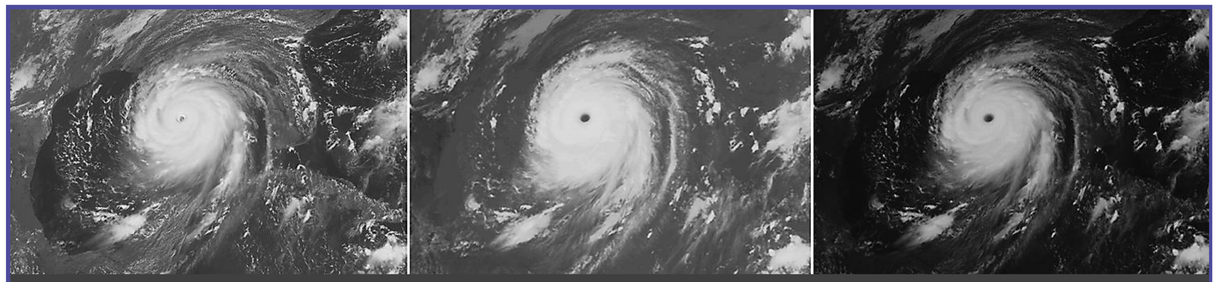
Hurricane Julio v. 1.0, in white ABS plastic. Another material, PLA, produces a nicer finish and is less likely to warp while printing.

In 2014, our first 3D-printable hurricane attracted some public interest, and even inspired a student to develop her own models as part of an information design project.[3] This response suggests a strong potential for engaging students and the public with physical storm models.

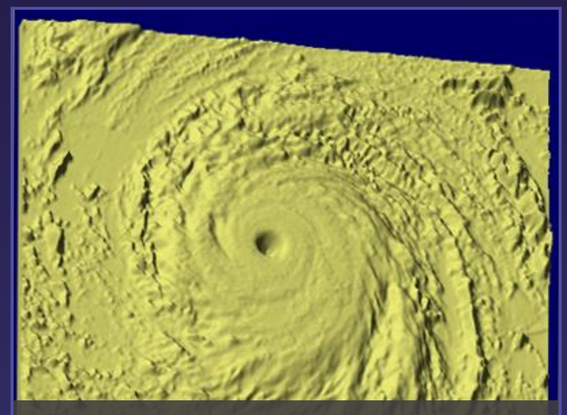
Educational opportunities arise from the end product itself. But a wide range of science-related skills accompany the research, development and printing of models like these. They include design, problem solving, and striking a balance between scientific accuracy and the need to clearly illustrate relationships (as in, for example, selecting a vertical exaggeration, or recognizing that high thin cirrus clouds become solid layers of different heights). An aspect of any modeling effort is an awareness of its compromises and limitations.



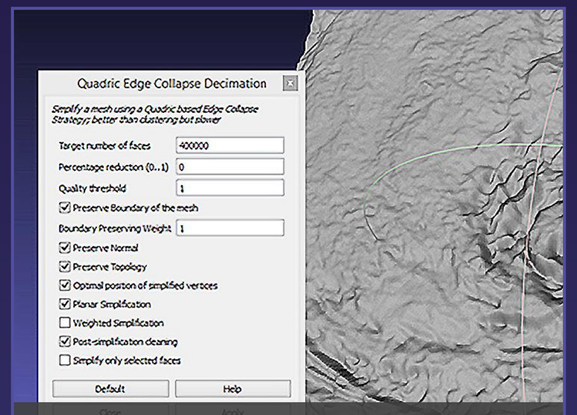
3D-printed models of hurricanes Katrina (left), Sandy (center) and Julio (right) were made by merging band 1 and band 4 GOES imagery and reprojecting to center on each storm. The models, which are printed in PLA plastic, have identical spatial scales (12.06 km/mm, or about 2350 km on a side) and vertical exaggeration (10 times). North is at top.



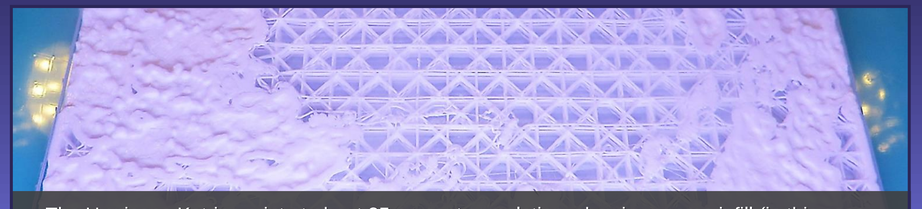
GOES 13 views of Hurricane Katrina from NOAA's CLASS archive. The visible view is at left and the thermal infrared is at center. On the right is a blend of these images made by using a photo editor's "multiply" mode. This suppresses clouds that are bright in the visible but dark in the IR (and therefore at lower altitudes) and largely removes ocean color differences, sun glint, and land areas. No other brightness or contrast changes were made to the images.



A 3D surface is generated by assigning a height to image pixels based on their brightness. The maximum height is selected based on the model's scale, the storm's highest clouds (~19 km for Katrina, shown here), and a vertical exaggeration of 10 times.



The original mesh was 109 MB in size with more than 1.1 million triangles. Using a quadratic edge collapse decimation filter, the polygon count was reduced to 400,000 triangles and the file size to 19 MB without substantially altering the mesh quality. Sandy shown.



The Hurricane Katrina print at about 25 percent completion, showing sparse infill (in this case, 10 percent) that makes up most of the model volume. Each infill layer was angled 45 degrees to the previous one, creating a grid-like foundation for solid surface layers.

Image to Print

The function to convert an image into a 3D mesh is available in many popular design and 3D-printing programs. However, the most widely seen satellite images contain color enhancements, grids, and coastline overlays that would be reflected in the generated mesh, which was undesirable for this project. GOES images in NOAA's CLASS library are available without these additions.

Full disk images were used for convenience in establishing scale and in cropping identical image areas for multiple storms. Images were selected for the highest sun angle in order to flatten lighting effects at visible wavelengths. Although not necessary for creating the mesh, the full disk images were initially reprojected[4] to the center of each storm for improved comparisons between models.

Additional processing steps are described at left; the products used to develop the models and prepare them for printing are listed below.

Once created, the mesh (an STL file) can be further simplified with filters available in, for example, the open source program Meshlab. Before attempting to print, the mesh should be checked for errors and, if needed, automatically repaired using netfabb Basic, a free utility used for correcting common problems in these files.

The final step involves processing the model through software that produces the machine-specific code to be executed by the 3-D printer. Simplify3D was used for the prints shown here, and all of its process settings are included with the models as an XML file.

Software

PhotoToMesh V6	http://www.ransen.com
Meshlab v. 1.3.3	http://meshlab.sourceforge.net
netfabb Basic v. 5.2.1	http://www.netfabb.com
Simplify3D v. 2.2.2	https://www.simplify3d.com

Notes

1. NOAA's CLASS archive. http://www.class.noaa.gov
2. NASA's 3D Resources. http://nasa3d.arc.nasa.gov
3. Reichel, A. 3D Cyclones. http://www.annereichel.com
4. Gott, J. R., III, Mugnolo, C., and Colley, W. N. (2007). Map projections minimizing distance errors. *Cartographica*, 42, 3, 219–234. doi:10.3138/carto.42.3.219